2017 Western Asio flammeus Landscape Study (WAFLS) Annual Report

Short-eared Owl in flight, southern Idaho, July 4, 2017, Kathy Lopez (3-year WAFLS volunteer).

Robert A. Miller[a,1], Neil Paprocki[b], Bryan Bedrosian[c], Cris Tomlinson[d], Jay D. Carlisle[a], and Colleen Moulton[e]

[a]Intermountain Bird Observatory, Boise, Idaho, USA
[b]HawkWatch International, Salt Lake City, Utah, USA;
[c]Teton Raptor Center, Wilson, Wyoming, USA;
[d]Nevada Department of Wildlife, Las Vegas, Nevada, USA;
[e]Idaho Department of Fish and Game, Boise, Idaho, USA

[1]Correspending author: RobertMiller7@boisestate.edu; 208-860-4944

Significance Statement

WAFLS is the largest geographic survey of Short-eared Owls in the world. The abundance estimates and habitat associations from this effort provides critical insight to land managers across the Intermountain West to influence species-specific and general conservation actions.

ABSTRACT

The Short-eared Owl is an open-country species that breeds in the northern United States and Canada, and has likely experienced a long-term, range-wide population decline. However, the cause and magnitude of the decline is not well understood. Following Booms et al. (2014), who proposed six conservation actions for this species, we set forth to address four of these objectives within this program: 1) better define and protect important habitats; 2) improve population monitoring; 3) better understand owl movements; and 4) develop management plans and tools. Population monitoring of Short-eared Owls is complicated by the fact that the species is an irruptive breeder with low site fidelity, resulting in large swings in local breeding densities, often tied to fluctuations in prey density. It is therefore, critical that any monitoring effort be implemented on a broad enough scale to catch regional shifts in distribution that are expected to occur annually. We recruited 330 participants, many of which were citizen-science volunteers, to survey over 41 million ha within the Intermountain West states of Idaho, Nevada, Utah, and Wyoming during the 2017 breeding season. We surveyed 181 transects, 163 of which were surveyed twice, and detected Short-eared Owls on 18 transects. We performed multi-scale occupancy modeling, multi-scale abundance modeling, and maximum entropy modeling to identify population status, habitat and climate associations. While we had an insufficient number of detections this year for specific abundance estimation, our occupancy rates suggest a significant decrease in population size this breeding season in Idaho and Utah, possibly exceeding 60%, as compared to recent years. As expected, our occupancy modeling found that the probability of detecting Short-eared Owls was impacted by the time of the survey and local wind conditions. We most often found Short-eared Owls in areas with moderate levels of grazing, exceeding areas with no grazing and those where the whole landscape was open to grazing, an association we have not found in past years. Consistent with recent years, Short-eared Owls were more likely in areas of shrubland, cropland, and marshland, and less likely in areas of grassland. On the surface, our results may seem contradictory to the presumed land use by a “grassland” species; however, many of the grasslands of the Intermountain West, consisting largely of invasive cheatgrass, lack the complex structure shown to be preferred by these owls. Our results suggest that Short-eared Owls have a climate association that puts them at great future risk, primarily their apparent preference of landscapes with high precipitation and moderate seasonality. As our summers continue to dry, as is expected under most climate scenarios, we would expect a further decrease in the population of this species, possibly through the climate’s effect on prey abundance. As a result of the consistent results across the broad scale of the program, we have established with high confidence that the breeding density of Short-eared Owls in 2017 was much lower than recent years and that the birds did not simply shift distribution within the region. Lastly, our results demonstrate the feasibility, efficiency, and effectiveness of utilizing public participation in scientific research (i.e., citizen scientists) to achieve a robust sampling methodology across the broad geography of the Intermountain West. We look forward to the continued expansion of this program in future years.

Key Words: citizen-science | conservation | habitat use | occupancy | population trend | Short-eared Owl

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INTRODUCTION

The Short-eared Owl (*Asio flammeus*) is a global open-country species often occupying tundra, marshes, grasslands, and shrublands (Holt et al. 1999, Wiggins et al. 2006). In North America, the Short-eared Owl breeds in the northern United States and Canada, mostly wintering in the United States and Mexico (Wiggins et al. 2006). Swengel and Swengel (2014) conducted surveys for this species in seven midwestern states, finding Short-eared Owls breeding in larger intact patches of grassland (>500ha) with heavy plant litter accumulation, and little association with shrub cover. Within Idaho, Miller et al. (2016) found positive associations with shrubland, marshland and riparian areas at a transect scale (1750ha), and with certain types of agriculture (fallow and bare soil) and a negative association with grassland at a point scale (50ha). However, until now habitat use has not been broadly explored within the Intermountain West of North America.

Booms et al. (2014) argued that the Short-eared Owl has experienced a long-term, range-wide, substantial decline in North America. To support their claim, they summarized Breeding Bird Survey and Christmas Birds Count results from across North America (National Audubon Society 2012, Sauer et al. 2017). Table 1 illustrates the general downward trend in Short-eared Owl populations in western North America between 1966 and 2015 (note the region-wide values), as estimated from the Breeding Bird Survey; however, only California had sufficient sample size for a significant result (Sauer et al. 2017). Booms et al. (2014) acknowledge that neither the Breeding Bird Survey nor Christmas Bird Count adequately sample the Short-eared Owl population in North America as the species is not highly vocal and is most active during crepuscular periods and at night, resulting in very few detections.

Table 1. Annual Breeding Bird Survey (BBS) trends in regions of the western United States from 1966 – 2015 (Sauer et al. 2017) with 95% confidence intervals. Only California evaluated out to 50 years had a statistically significant result†, illustrating the potential lack of measurement power of the BBS methodology to evaluate Short-eared Owl populations.

Region	Sample	50-Year Rate	95% CI	10-Year Rate	95% CI
California	7	-6.70	(-11.19, -2.59)	-6.64	(-14.89, 2.14)
Idaho	22	-2.72	(-6.80, 0.63)	-3.97	(-17.84, 6.00)
Montana	43	1.33	(-2.53, 5.01)	7.09	(-5.97, 21.83)
Nevada	9	2.58	(-4.14, 9.61)	4.3	(-9.57, 42.11)
Oregon	28	-1.24	(-4.07, 1.84)	-0.6	(-5.36, 12.34)
Utah	19	1.03	(-6.34, 9.44)	-6.07	(-22.88, 12.41)
Washington	25	-2.48	(-6.64, 1.95)	-8.69	(-22.77, 4.14)
Wyoming	33	0.08	(-4.90, 4.95)	19.2	(-1.16, 46.81)
Great Basin	110	-1.56	(-4.12, 0.64)	-3.43	(-10.18, 4.80)
Western BBS	133	-0.95	(-3.33, 1.04)	-1.8	(-7.68, 5.14)

†Statistical significance measured with 95% Confidence Interval failing to overlap zero.

Relative to winter range, Langham et al. (2015) used Breeding Bird Survey data, Christmas Bird Count data and correlative distribution modeling with various future emission scenarios to predict distribution shifts of North American bird species in response to future climate change. Their results predict that 90% of the winter range of Short-eared Owls in the year 2000 may no longer be occupied by 2080 and, even with a northward shift in winter range, the total area of winter range is expected to reduce in size by 34% (National Audubon Society 2014).

Booms et al. (2014) and Langham et al. (2015) have highlighted the apparent disconnect of current and predicted population trends of Short-eared Owls and current conservation priorities. Booms et al. (2014) proposed six measures to better understand and prioritize actions associated with the conservation of this species. We have chosen to focus on the four of those measures: 1) better define and protect important habitats; 2) improve population monitoring; 3) better understand owl movements; and 4) develop management plans and tools (Booms et al. 2014).

Public participation in scientific research, sometimes referred to as citizen science, can take many forms ranging from contributory to contractual (Shirk et al. 2012). Public participation in scientific research has a long history of contributing data critical to the monitoring of wildlife (e.g., Breeding Bird Surveys [Sauer et al. 2014], Christmas Birds Counts [National Audubon Society 2012], eBird data for conservation [Callaghan and Gawlik 2015], and Monarch Butterfly monitoring [Ries and Oberhauser 2015]). Public participation projects can deliver benefits to multiple constituents including the volunteers themselves, the lead researchers and the conservation community and general public. For a contributory project, the volunteer gains increased content knowledge, improved science inquiry skills, appreciation of the complexity of ecosystems and ecosystem monitoring, and increased technical monitoring skills (Shirk et al. 2012). The primary advantage to the researcher for a contributory project is at the project scale (decreased cost, increased sample size and geographical scale; Shirk et al. 2012). Researchers must structure programs appropriately to achieve desired results, as unstructured citizen science data collection may not provide sufficient resolution to meet the program objectives (Kamp et al. 2016).

Student volunteers from Owyhee Combined School Science Club surveying grid Idaho-026, April 8, 2017. This represents the science club's second year participating in the WAFLS program. Photo by Barbara Pete.

The WAFLS program began in 2015 with an Idaho state-wide program and a limited pilot in northern Utah (Miller et al. 2016). In 2016, we expanded to an Idaho and Utah state-wide program. In 2017, we once again expanded, this time into the neighboring states Nevada and Wyoming. Our program objectives include: 1) identify habitat use by Short-eared Owls during the breeding season in the Intermountain West; 2) establish a baseline population estimate to be used to evaluate population trends; 3) develop a monitoring framework to evaluate population trends over time; and 4) evaluate if these objectives can be met by using a large network of citizen science volunteers through contributory public participation in a scientific research framework as described by Shirk et al. (2012).

METHODS

Study area

Our 2017 study area included the states of Idaho, Nevada, Utah, and Wyoming within the Intermountain West of the United States. We stratified this region by first laying a 10km by 10km grid over the four states, and within these grid cells, we quantified presumed Short-eared Owl habitat within our study area using Landfire data (US Geological Survey 2012). Grassland, shrubland, marshland/riparian, and agriculture land cover classes were considered to be potential Short-eared Owl habitat (Wiggins et al. 2006). Grids with at least 70% land cover consisting of any of these four classes were considered in our survey stratum. All other grids were then removed from further consideration. The result consisted of 9,460,000ha within the Idaho stratum, primarily in southern and west-central Idaho, 10,260,000ha within Nevada, 7,760,000ha within Utah, and 13,810,000ha within Wyoming (Fig. 1).

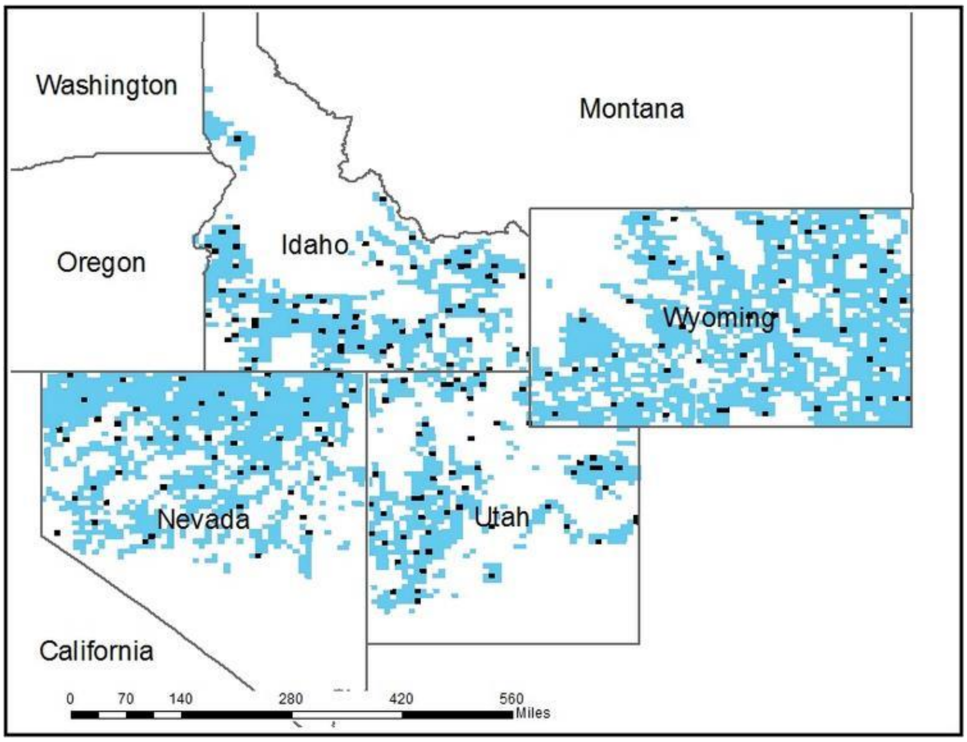

Figure 1. Distribution of strata (blue squares) and spatially-balanced survey transects (black squares) for Short-eared Owl surveys during the 2017 breeding season across the states of Idaho, Nevada, Utah, and Wyoming, within the Intermountain West.

Transect selection

We selected survey transects within the stratum using a spatially-balanced sample of 10km by 10km grid cells using a Generalized Random-Tessellation Stratified (GRTS) process (Stevens Jr. and Olsen 2004). We eliminated grid cells with no secondary roads, a requirement of our road-based protocol. We selected a spatially-balanced sample of 50 grid cells per state (Fig. 1). We selected additional groups of randomly-selected grid cells in each state in groups of ten that could be offered up to additional volunteers only if the original 50 grid cells were all committed. These additional surveys were integrated into the analysis in the same manner as the base 50. Only one additional group of surveys were offered to volunteers, in Idaho.

We delineated a survey route within each grid along a 9km stretch of secondary road (Fig. 2), the maximum survey length feasible using the protocol and our justification for choosing a 10km by 10km grid structure (Larson and Holt 2016). If multiple possible routes were available within a single grid cell, we chose routes expected to have the least traffic, routes on the edge of the greatest amount of roadless habitat, or routes with the highest likelihood of detecting Short-eared Owls (a potential source of bias discussed later). In some cases, such as road access issues, the surveys were allowed to extend outside of the grid cell, but never for habitat quality purposes. Larson and Holt (2016) report that in favorable conditions Short-eared Owls can be correctly identified up to 1600m away, with high detectability up to 800m. Calladine et al. (2010) had a mean initial detection distance of 500 - 700m, with a maximum recorded value of 2500m. As our analysis method is robust against false negative detections, but less so against false positive detections, we chose to assume a larger average initial detection distance of 1km. Therefore, we considered all land within 1km of the surveyed points as sampled habitat (Fig. 2).

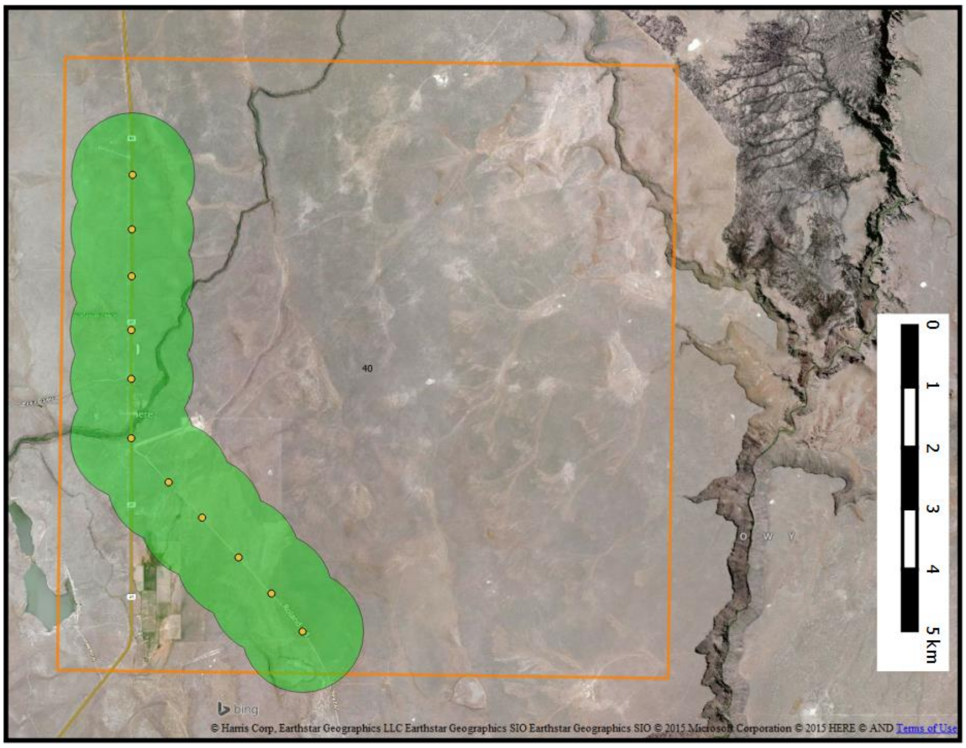

Figure 2. Example illustration of 10km × 10km grid cell (orange), 11 road-based survey points (yellow), and area surveyed within 1km of survey points (green). Green-shaded area is only area used in the analysis.

Hot-spot grids
In Idaho and Utah, we also sampled hot-spot grids. These were non-randomly selected grids located in places that we expected to find Short-eared Owls. The grids are intended to look at relative abundance among these sites from year to year. We implemented a consistent protocol for sampling these grids, but did not include the results in the habitat or abundance analyses as they do not meet the assumptions of these analyses and would have biased our results.

Public participation recruitment
We recruited citizen science volunteers to complete survey routes. We used a combination of partnerships, listservs, social media, and personal contacts to complete our roster. Our most successful recruiting tool was to reach out to existing volunteer organizations such as naturalist groups and birding groups, electronically, through submitted newsletter articles, and in person. In some cases, we reached out to professional biologists to cover remote grids or grids on restricted lands (e.g., reservation lands or national laboratory lands closed to the public). The reliance on professional biologists differed among the states. For example, Nevada Department of Wildlife in addition to recruiting volunteers, invited a network of professional biologists that they have engaged for their winter raptor survey routes. The result is that we had a larger proportion of paid biologists surveying in Nevada than in other states.

We began recruiting volunteers two months prior to the beginning of the survey window. Across the four states, roughly ⅔ of our volunteers were non-professional citizen scientists, whereas ⅓ were professional biologists either volunteering to survey routes or assigned by their agency or company to complete the route (e.g., restricted lands). We originally offered 50 grids in each state. After we recruited volunteers for all 50 grids in Idaho, we offered 10 additional grids. We successfully recruited volunteers for 60 grids in Idaho, 38 in Nevada, 50 in Utah, and 50 in Wyoming. The difference between the originally selected number of grids (e.g., 60 in Idaho) and those successfully surveyed (50 in Idaho) was the result of volunteers failing to complete the survey (essentially a random sample of missed surveys). Our historical rate of route non-completion among volunteers is 10 – 15%.

We provided training materials (e.g., owl identification), a procedure manual, maps, civil twilight schedules and datasheets to volunteers to help ensure survey quality. One formal training session was held for volunteers in Utah, which was attended by ~35 volunteers. We also provided volunteers who could not make the formal training session with a freely accessible YouTube training video, which has been viewed 248 times. We asked volunteers to submit data via an online portal utilizing Jotform's online service.

Owl surveys

Observers attempted to complete two surveys per transect. Each survey window was three weeks long for the first visit and another three weeks for the second visit. Survey windows were adjusted for each route based upon elevation (Table 2). Survey timing was chosen to attempt to coincide with the period of highest detectability during the courtship period when male owls perform elaborate courtship flights (Fig. 3). Volunteers could choose any day within their survey window to perform their survey, however we asked volunteers to separate the two visits by at least one week.

Table 2. Suggested survey timing for each of the two visits derived from mean elevation of the survey grid and expected courtship period of Short-eared Owls within each participating state.

Idaho	Elevation below 4000ft.	Elevation 4000 - 6000ft.	Elevation above 6000ft.	
Visit 1	March 1 - March 21st	March 16 - April 7th	April 1st - April 21st	
Visit 2	March 22nd - April 15th	April 8th - April 30th	April 22nd - May 15th	
Nevada	Elevation below 5000ft.	Elevation 5000 - 6000ft.	Elevation above 6000ft.	
Visit 1	March 1 - March 21st	March 16 - April 7th	April 1st - April 21st	
Visit 2	March 22nd - April 15th	April 8th - April 30th	April 22nd - May 15th	
Utah	Elevation below 5000ft.	Elevation 5000 - 6000ft.	Elevation above 6000ft.	
Visit 1	March 1 - March 21st	March 16 - April 7th	April 1st - April 21st	
Visit 2	March 22nd - April 15th	April 8th - April 30th	April 22nd - May 15th	
Wyoming	Elevation below 5000ft.	Elevation 5000 - 6000ft.	Elevation 6000 - 7000ft.	Elevation above 7000ft.
Visit 1	March 10 - March 31st	March 24 - April 14th	April 7th - April 28th	April 14th - May 5th
Visit 2	April 1st - April 22nd	April 15th - May 6th	April 29th - May 20th	May 6th - May 27th

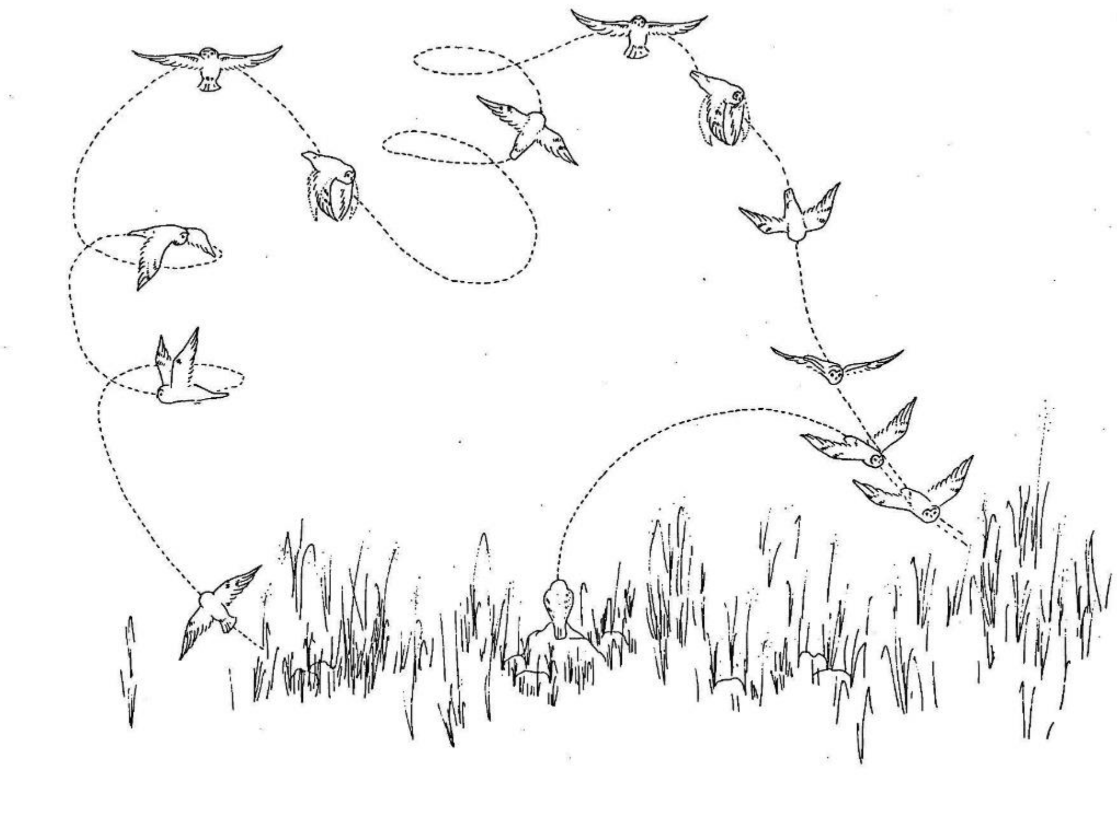

Figure 3. Illustration of male courtship display flight (Wiggins et al. 2006; included with permission).

Observers surveyed points separated by approximately ½ mile (800m) along secondary roads from 100 to 10 minutes prior to the end of local civil twilight, completing as many points as possible (8 – 11 points) during the 90-minute span (Larson and Holt 2016). The multi-scale analyses methods we used relax the assumption of point independence enabling the intermediate point spacing with overlapping area surveyed (i.e., 800m spacing instead of 2000m).

At each point observers performed a five-minute point count, noting each individual bird minute-by-minute (i.e., with replacement; e.g., for an owl observed only during minutes 2 and 3 of the five-minute period, we would assign a value of “01100”). For each observation of a Short-eared Owl, observers recorded whether the bird was seen, heard (hoots, barks, screams, wing clip, bill snap), or both, and what behaviors were observed (perched, foraging, direct flight, agonistic, courtship).

Habitat data

At each point observers collected basic habitat data during each visit as we expected some land cover to change during the period (e.g., agricultural field may have been plowed and the cover could therefore change from stubble to bare soil between visits). Observers noted the proportion of habitat within 400m of the point (in general, about half the distance between survey points) that consisted of tall shrubland (above knee height), low shrubland (below knee height), cheatgrass mono-culture, complex grassland, marshland, fallow agriculture, retained stubble agriculture, plowed soil agriculture, and green agriculture (new green plant growth visible; Table 3; See Appendix III for full protocol). Mixed grassland and shrubland was classified as shrubland if there were at least shrubs regularly distributed through the area. We also had volunteers count the number of visible livestock and estimate the proportion of the point radius open to livestock grazing. The grass categories of cheatgrass mono-culture and complex grassland, represent an evolution from previous years where we simply collected grass height. We have assumed that these categories better represent the attributes that may be preferred by Short-eared Owls.

Table 3. Definition, variable name used in models, mean, standard deviation (SD), range, position within multi-scale hierarchy, and source of covariates evaluated for influence in occupancy and abundance analysis of Short-eared Owls within during the 2017 breeding season.

Variable	Name in Models	Mean ± SD	Range	Hierarchy	Source
Temperature	Temp	57 ± 9	30 – 77	Detection	Survey
Wind (beaufort)	Wind	2.3 ± 1.4	0 – 6	Detection	Survey
Sky (1 – 4)	Sky	2.9 ± 1.2	1 – 4	Detection	Survey
Day-of-year	julian	101 ± 19	60 – 152	Detection	Survey
Minutes before civil twilight	minCiv	63 ± 27	-26 – 181†	Detection	Survey
Low shrub 400m	lShr	48 ± 37	0 – 100	Point-scale Avail.	Survey
High shrub 400m	hShr	34 ± 33	0 – 100	Point-scale Avail.	Survey
Cheatgrass monoculture 400m	cheat	18 ± 27	0 – 100	Point-scale Avail.	Survey
Complex grassland 400m	hGr	40 ± 33	0 – 100	Point-scale Avail.	Survey
Marsh 400m	marsh	10 ± 16	0 – 100	Point-scale Avail.	Survey
Fallow ag 400m	fallow	13 ± 21	0 – 100	Point-scale Avail.	Survey
Stubble ag 400m	stubble	18 ± 29	0 – 100	Point-scale Avail.	Survey
Dirt ag 400m	dirt	18 ± 27	0 – 100	Point-scale Avail.	Survey
Green ag 400m	green	27 ± 31	0 – 100	Point-scale Avail.	Survey
Grazing 400m	graze	44 ± 43	0 – 100	Point-scale Avail.	Survey
Livestock 400m	ls	16 ± 58	0 – 1500	Point-scale Avail.	Survey
Sagebrush 1km	Sageland	0.32 ± 0.31	0.00 – 0.99	Occupancy/Abundance	GIS
Shrubland 1km	Shrubland	0.32 ± 0.30	0.00 – 0.96	Occupancy/Abundance	GIS
Grassland 1km	Grassland	0.14 ± 0.24	0.00 – 0.95	Occupancy/Abundance	GIS
Cropland 1km	Cropland	0.10 ± 0.18	0.00 – 0.79	Occupancy/Abundance	GIS
Marshland 1km	Marshland	0.01 ± 0.02	0.00 – 0.12	Occupancy/Abundance	GIS

†All survey points started prior to 120 minutes before the end of civil twilight were dropped from the analysis.

The primary changes in field methods from 2016, were the inclusion of the Nevada and Wyoming strata, and change in how grass is measured at the point-scale (cheat-grass monoculture and complex grassland versus low of high grasses).

Statistical analysis

We performed multi-scale occupancy modeling (Nichols et al. 2008, Pavlacky et al. 2012), multi-scale abundance modeling (Chandler et al. 2011, Sparks et al. *In Review*), and Maximum Entropy modeling (MaxEnt; Phillips et al. 2006, 2017). Multi-scale occupancy modeling was chosen for its strength in evaluating fine-scale (point-scale in our case) habitat associations and providing a more refined alternative to abundance estimation. Multi-scale abundance modeling was chosen for when we have sufficient detections to get specific state-level population size estimates. MaxEnt modeling provides study-wide habitat mapping, integrating current and future climate scenarios into the predictions.

Multi-scale Occupancy and Abundance Modeling

For multi-scale occupancy modeling we implemented a minute-by-minute replacement design, allowing for simultaneous evaluation of detection, point-scale occupancy, and transect-scale occupancy (Nichols et al. 2008). Similar to Pavlacky et al. (2012) we used a modified version of Nichols et al. (2008) where the point-scale occupancy uses spatial replicates, but unlike Pavlacky et al. (2012) we also included our temporal replicates (i.e., two visits) essentially producing a model where the Θ parameter represents a combination of point-scale occupancy and point-scale availability.

For the multi-scale abundance analyses we implemented a modified, open population, *N*-mixture model with a Poisson distribution (Chandler et al. 2011, Sparks et al. *In Review*). Similar to the occupancy modeling, we deviated from Chandler et al. (2011) by utilizing spatial replicates for point-scale occupancy (Sparks et al. *In Review*), along with our temporal replicates producing a model where the Φ parameter represents a combination of point-scale occupancy and point-scale availability. Both analysis methods are robust to missing data, allowing us to include surveys with differing numbers of points (8 – 11) and the transects that were only surveyed once.

For multi-scale occupancy and multi-scale abundance analysis, we collected transect level data using Geographic Information System (GIS) analysis by buffering all surveyed points by 1km, the presumed average maximum detection distance, and quantifying the proportion of each habitat type from the 2012 Landfire dataset (Table 2; US Geological Survey 2012).

Within each analysis approach (occupancy and abundance) we evaluated variables influencing the probability of detection (day-of-year, minutes-before-civil-twilight, wind, sky cover, etc.), availability at the point scale (vegetation and grazing values collected by observers within 400m of point, ~50ha), and transect occupancy or abundance (habitat types collected through GIS data within 1km of all sampled points; Table 2). The 10km by 10km grid structure was only used to distribute and spatially balance the transects, all analyses only utilized the 1750ha area surrounding the points actually surveyed (1km radius buffer).

For both the multi-scale occupancy and multi-scale abundance analyses we used a sequential, parameter-wise model building strategy (Lebreton et al. 1992, Doherty et al. 2010), ranking models using Akaike Information Criterion adjusted for small sample size (AIC_c; Burnham and Anderson 2002). For each type of multi-scale modeling (occupancy and abundance), we first evaluated each variable by assessing the null model, the model with just the variable of interest, and the model with the variable of interest and the square of the variable of interest. We eliminated the variable from further consideration if the null model ranked highest, otherwise we propagated forward the highest ranking of the variable of interest or the variable and it's square. We first selected candidate variables influencing the probability of detection (*p*) by considering all combinations of the retained variables and chose all variables appearing in models within two ΔAIC_c of the top model. We then fixed the variable set for probability of detection and repeated the procedure for variables influencing the occupancy/availability at the point-scale (Θ [for occupancy modeling], Φ [for abundance modeling]). Lastly we repeated the procedure for variables influencing transect occupancy (Ψ) or transect abundance (Λ) to arrive at our final model set for each analysis.

For inference we used model averaging of all models falling within two ΔAIC_c of the top model, that also ranked higher than the null model (Burnham and Anderson 2002). For each variable appearing within this final model set for the occupancy analysis, we created and present model averaged predictions by ranging the variable of interest over its measured range while holding all other variables at their mean value. For the state-wide abundance estimate we extrapolated the estimated average transect abundance from our top model, back to the total area of our sampled stratum.

Maximum Entropy Modeling
For the MaxEnt analyses, we used the same base Landfire dataset (US Geological Survey 2012), but integrated in a different way. We produced study-wide raster maps of the proportion of each cover type within 150m of each 30m × 30m pixel on the landscape (e.g., shrubs, sage, grass, etc.). Similarly, we created study-wide maps of elevation, slope, roughness, and an ecological relevant sample of the 19 standard climate variables derived from 1960 – 1990 (worldclim.org; Hijmans et al. 2005; Table 4). All values were then resampled down to 30-second blocks (~1km; resolution of the climate data) using bilinear interpolation. We used all presence and pseudo-absence (locations that we failed to detect owls, but cannot be certain that they were absent) observations from the past three years in the analysis (2015, 2016, and 2017). The result is that the model best represents Idaho with three years of data, then Utah with two years of data, and lastly Nevada and Wyoming with the most limited data. We evaluated the MaxEnt model feature class (linear, quadratic, hinge) and regularization parameters (0.5 – 4.0) using AIC_c (Shcheglovitova and Anderson 2013).

Table 4. Climate, geographic, and habitat variables and source of variables included in MaxEnt analysis.

Variable	Source
Annual Mean Temperature (°C)	worldclim.org bio_1
Mean Diurnal Range (Mean of monthly (max temp - min temp)) (°C)	worldclim.org bio_2
Temperature Seasonality (standard deviation *100)	worldclim.org bio_4
Max Temperature of Warmest Month (°C)	worldclim.org bio_5
Annual Precipitation (mm)	worldclim.org bio_12
Precipitation of Wettest Month (mm)	worldclim.org bio_13
Precipitation of Driest Month (mm)	worldclim.org bio_14
Precipitation Seasonality (Coefficient of Variation)	worldclim.org bio_15
Elevation (m)	USGS DEM
Slope	USGS DEM
Roughness	USGS DEM
Proportion Cropland within 150m	Landfire
Proportion Marshland within 150m	Landfire
Proportion Grassland within 150m	Landfire
Proportion Shrubland within 150m	Landfire

For future climate projections, we used the same top MaxEnt model, but applied future climate model data instead of recent climate data. Future climate data were derived from the Fifth Assessment of the Intergovernmental Panel on Climate Change (IPCC AR5) using the Hadley Centre Global Environment Model version 2 and Representative Conservation Pathway 4.5 projected to the year 2070 (RCP4.5; Moss et al. 2008). This dataset assumes a radiative forcing value of +4.5 in the year 2100 relative to pre-industrial values, a conservative model that assumes considerable reductions in the rate of growth in current greenhouse gas emissions. For the future projections, we held the habitat variables at their current level, an assumption that is not likely to hold true as changes in climate will likely result in changes in habitat available.

We present graphical representations of estimated effect size with 95% confidence intervals to align with the majority of scientific literature, whereas, we present abundance estimates with 80% confidence intervals to more closely align with local management objectives. We conducted all statistical analyses in Program R and Program Mark (White and Burnham 1999, R Core Team 2017). We used the R package "RMark" to interface between Program R and Program Mark for the multi-scale occupancy modeling (Laake 2014). We used the R package "unmarked" to perform the multi-scale abundance modeling (Fiske and Chandler 2011). We used R package "AICcmodavg" to rank all models (calculating AIC_c), and to perform model averaging (Mazerolle 2015). We used R package "dismo" (Hijmans et al. 2017), interfacing with the MaxEnt software engine (Phillips et al. 2017), for all MaxEnt analyses. We used R package "ENMeval" for ranking and evaluating MaxEnt models (Muscarella ela. 2014).

RESULTS

A total of 330 individuals participated in the survey portion of the program (Appendix I & II), contributing 2815 volunteer hours, 435 non-federal paid hours, and 165 paid federal hours (Table 5). Participants traveled 56,468 miles to complete the surveys (Table 6), some of which presented travel challenges.

Table 5. Hours invested and value of contribution for volunteers, non-federal paid biologists, and federal paid biologists (based on standard volunteer rate for each state; Idaho=$21.10/hr, Nevada=$21.51/hr, Utah=$24.27/hr, Wyoming=$22.13/hr) by state.

State	Participants	Volunteer hours	Volunteer $	Non-fed hours	Non-fed $	Fed hours
Idaho	111	1003	$21,170	14	$295	25
Nevada	47	226	$4,861	172	$3,694	120
Utah	105	976	$23,691	112	$2,718	20
Wyoming	67	610	$13,488	138	$3,043	0
Total	330	2815	$63,211	435	$9,751	165

Table 6. Miles traveled and value of contribution for volunteers, non-federal paid biologists, and federal paid biologists (based on standard rate of $0.535/mile) by state.

State	Volunteer Miles	Volunteer $	Non-fed. Paid Miles	Non-fed. Paid $	Fed. Paid Miles	Fed. Paid $
Idaho	11,234	$6,010	192	$103	436	$233
Nevada	3,116	$1,667	4,714	$2,522	2,473	$1,323
Utah	17,548	$9,388	3,049	$1,631	318	$170
Wyoming	9,098	$4,867	4,019	$2,150	272	$146
Total	40,995	$21,933	11,974	$6,406	3,499	$1,872

Challenging travel conditions. Photo: Joanna Kane, Utah-082, April 15, 2017.

Challenging travel conditions. Photo: Tana Peery Hunter, Utah-023, April 16, 2017

In 2017, we successfully surveyed 181 total grids, 174 regular random grids and 7 hot-spot grids (Table 7). We detected Short-eared Owls on 18 grids. The grids where owls were detected were roughly geographically dispersed (Fig. 4).

Table 7. Total number of regular grids surveyed and grids with detections of owls, broken out by which visit, whether the grid was a random grid (regular) or hotspot grid, and by state.

State	Regular Grids	Regular W/ Owls	Regular Round 1	Regular Round 2	Hotspot Round 1	Hotspot Round 2
Idaho	50	4	3/50	4/43	3/3	3/3
Nevada	34	2	1/34	2/33		
Utah	47	4	2/47	2/42	2/4	2/4
Wyoming	43	3	2/43	2/38		

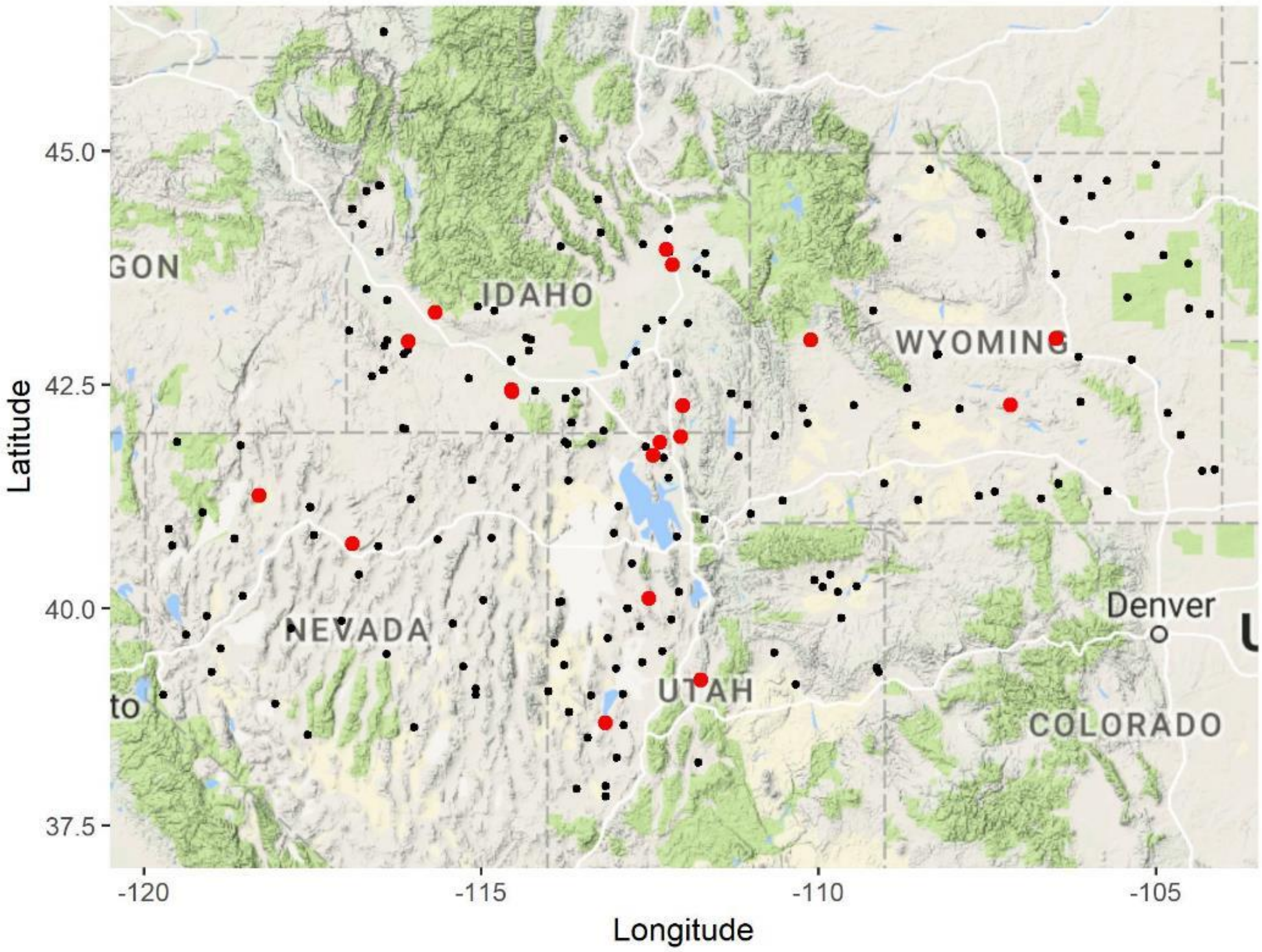

Figure 4. Locations of completed WAFLS surveys (regular and hot-spot) with no Short-eared Owl detections (black), and with Short-eared Owl detections (red).

Multi-scale Occupancy Modeling

The model selection process for the multi-scale occupancy analysis produced three models falling within two ΔAIC_c of the top model (Table 8). Wind and minutes-before-civil-twilight appeared in two and one models, respectively, influencing the probability of detection of at least one Short-eared Owl, given that at least one owl was present (Table 8, Fig. 5).

Table 8. Top model set, and the null model for comparison (shaded), for multi-scale occupancy analysis predicting the occupancy of transects by Short-eared Owls during the 2017 breeding season. k is the number of parameters in the model, AIC_c is Akaike's Information Criterion adjusted for small sample size, ΔAIC_c is the difference in AIC_c values between individual models and the top model, and w_i is the model weight. We only presented models where $\Delta AIC_c \leq 2.00$, the set used to generate model averaged predictions, and the null model for comparison.

Model	k	AIC_c	ΔAIC_c	w_i
$\Psi(.)\ \Theta(\text{graze} + \text{graze}^2)\ p(\text{wind})$	6	469.87	0.00	0.52
$\Psi(.)\ \Theta(\text{graze} + \text{graze}^2)\ p(\text{wind} + \text{minCiv})$	7	471.23	1.36	0.27
$\Psi(.)\ \Theta(\text{graze} + \text{graze}^2)\ p(.)$	5	471.67	1.80	0.21
$\Psi(.)\ \Theta(.)\ p(.)$	3	480.90	11.03	----

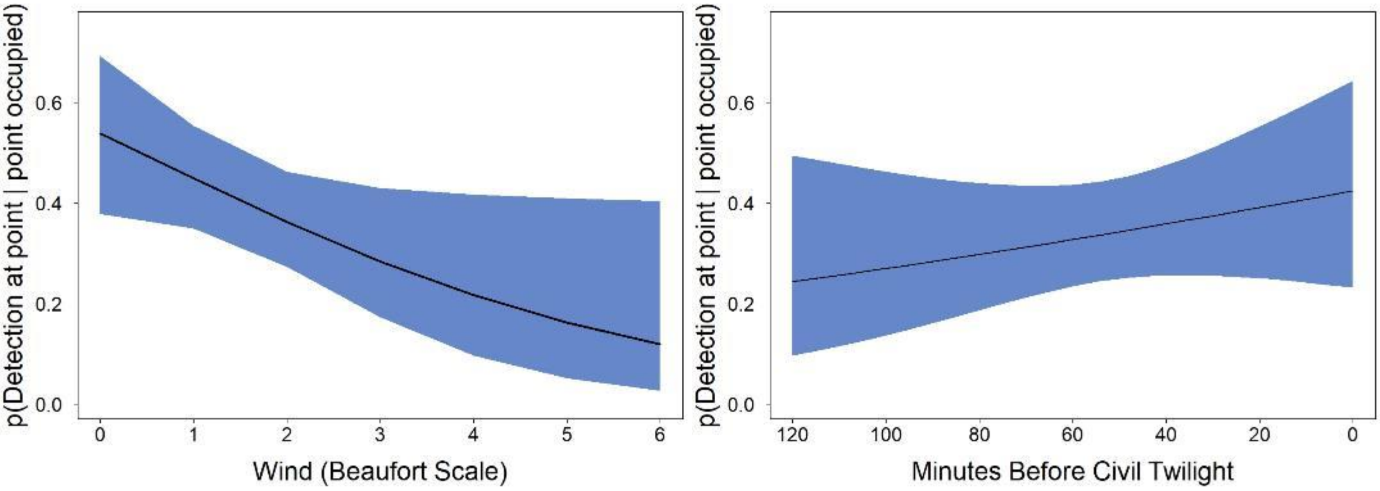

Figure 5. Model averaged prediction generated from multi-scale occupancy top model set for the effect size of a) wind; and b) minutes-before-civil-twilight on the probability of detecting at least one Short-eared Owl at a point given that there is at least one Short-eared Owl at the point during the 2017 breeding season. Black line = model prediction; blue = 95% confidence interval.

The proportion of land within 400m (~50ha) of the survey point that was being, or had previously been, grazed was selected as a variable influencing the probability of at least one Short-eared Owl at a point, given that at least one owl occupied the transect (Table 8, Fig. 6). The relationship was non-linear indicating that Short-eared Owls were more likely at points where grazing had occurred, but not too extensively (plenty of un-grazed habitat available; Fig. 6).

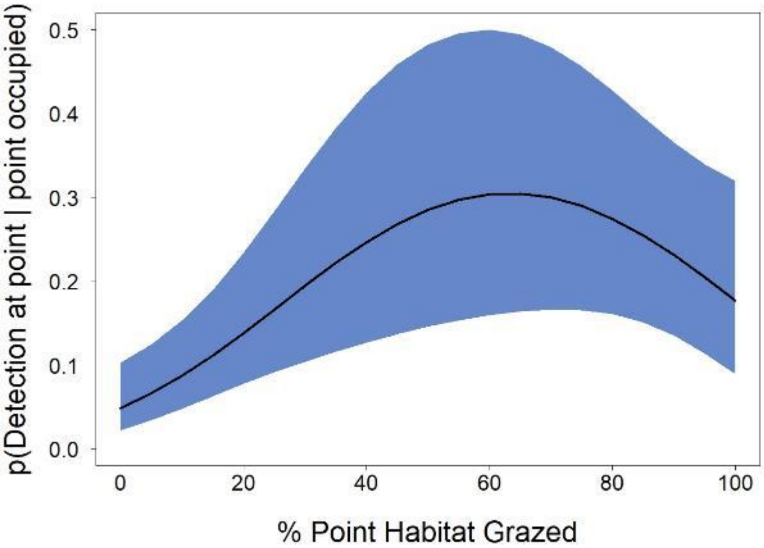

Figure 6. Model averaged predictions generated from multi-scale occupancy top model set for the effect size of the proportion of area within 400m of surveyed point that has been grazed, influencing the availability of at least one Short-eared Owl at the point to be sampled given that the transect was occupied by at least one Short-eared Owl during the 2017 breeding season. Black line = model prediction; orange area = 95% confidence interval.

No variables were selected influencing the presence of Short-eared Owls within the grid itself, likely the result of our low number of detections in 2017 (Table 8). Calculated grid occupancy, a surrogate for abundance, shows occupancy rates for Idaho at roughly 1/3 of the 2016 rate (Fig. 7). As the confidence intervals fail to overlap the other year's estimate, this is considered a significant result (Fig. 7). The decline appears to be less dramatic in Utah, however, we contracted the stratum to northern Utah so we were expecting an increase in occupancy rate within the smaller stratum.

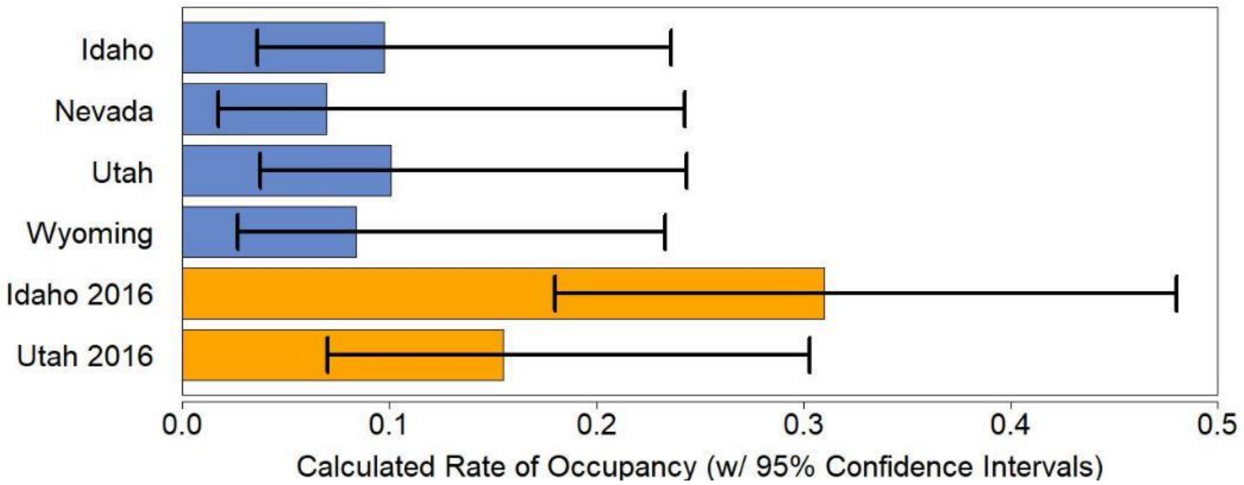

Figure 7. 2017 Estimated survey occupancy rates among the four states shown with 95% confidence intervals (blue) and 2016 results for comparison (orange). Note: rates for Utah are <u>not</u> directly comparable among years due to a stratum change, however, the stratum change was anticipated to increase the occupancy rate.

Multi-scale Abundance Modeling

After successful abundance modeling in 2015 and 2016, we had an insufficient number of detections in 2017 to adequately use this technique. However, looking at a consistent implementation in Idaho across years, and the large decrease in calculated occupancy rates (Fig. 7), we may conclude the breeding population in 2017 was much lower than both 2015 and 2016. Likewise, even though we changed the stratum used in Utah, a change that was expected to increase the estimated occupancy rates across the stratum by up to 50%, we saw a decrease (Fig. 7).

Spring conditions on WY-005. Photo: Tina Toth, March 13, 2017.

Maximum Entropy Modeling

The top model MaxEnt as evaluated with AIC_c was the hinge model with a 3.5 regularization parameter (Hinge 3.5). A similarly ranked model (linear-quadratic with regularization parameter 0.5 – LQ0.5) was within 2 ΔAIC_c (ΔAIC_c = 0.99). Since linear-quadratic models are more intuitive in nature, are generally less complex, and likely represent our newer states better (Nevada and Wyoming), we present predictions and variable effects from the MaxEnt modeling using this competitive model (LQ0.5). The use of the hinge model will be re-evaluated in future years.

The regularized training gain for LQ0.5 model built with all presence records was 0.43, and the Area Under the Curve of the receiver operating characteristic plot (AUC) was 0.76. From the jackknife test of variable importance, the single most important predictor variable, in terms of the gain produced by a one-variable model, was Precipitation of Wettest Month (worldclim.org bio_13), followed by Precipitation Seasonality (worldclim.org bio_15). Mean Diurnal Temperature Range (worldclim.org bio_2) and Precipitation Seasonality (worldclim.org bio_15) decreased the gain the most when they were omitted from the full model, which suggests they contained the most predictive information not present in the other variables.

Short-eared Owl in the snow. Photo: Hilary Turner, April 9, 2017.

The effect sizes, direction, and shape of the climate variables implemented in the MaxEnt model varied among variables (Fig. 8). Note that the effect sizes as reported individually are exaggerated when multiple correlated variables are included in the analysis. Since the climate variables are correlated, attention should be directed to the direction and shape of the curves and not the absolute values. Additionally, the effect sizes should be considered in aggregate, instead of too much individual attention.

Short-eared Owls within our study area were more likely found in locations where the temperature range, both daily and seasonally, is more restricted, annual temperatures are not too extreme, yet are warmer than average across the study area (Fig. 8). With regards to precipitation, Short-eared Owls were more likely found in locations with comparatively higher annual precipitation, available throughout the year (not simply in the wettest month, but also in the driest month), but not too evenly spread (moderate seasonality; Fig. 8).

Regarding the geographic and habitat features, there was less correlation among prediction variables, so the interpretation was easier. We found that Short-eared Owls were more likely to be detected at lower elevations, but not the lowest within our study area (Fig. 9). Short-eared Owls appeared to favor cropland, shrubland, and marshland, over grassland environments, both monotypic cheatgrass and more complex grasslands (Fig. 9).

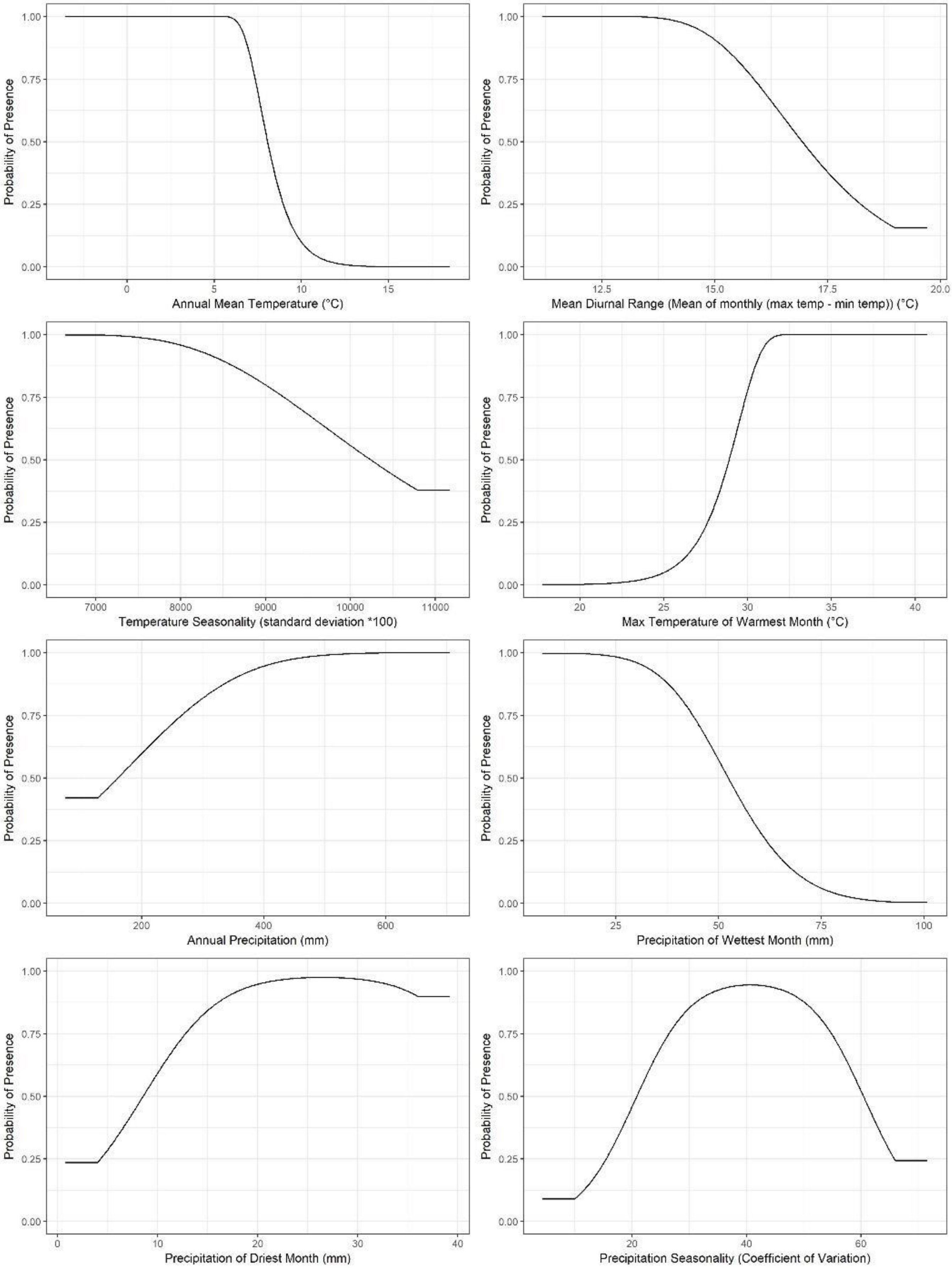

Figure 8. Response variable effect sizes for eight climate variables influencing Short-eared Owl presence, derived from MaxEnt model LQ0.5 using presence and pseudo-absence data from project WAFLS 2015, 2016, and 2017. Note: effect sizes may be amplified as a result of including highly correlated variables such as multiple climate related variables.

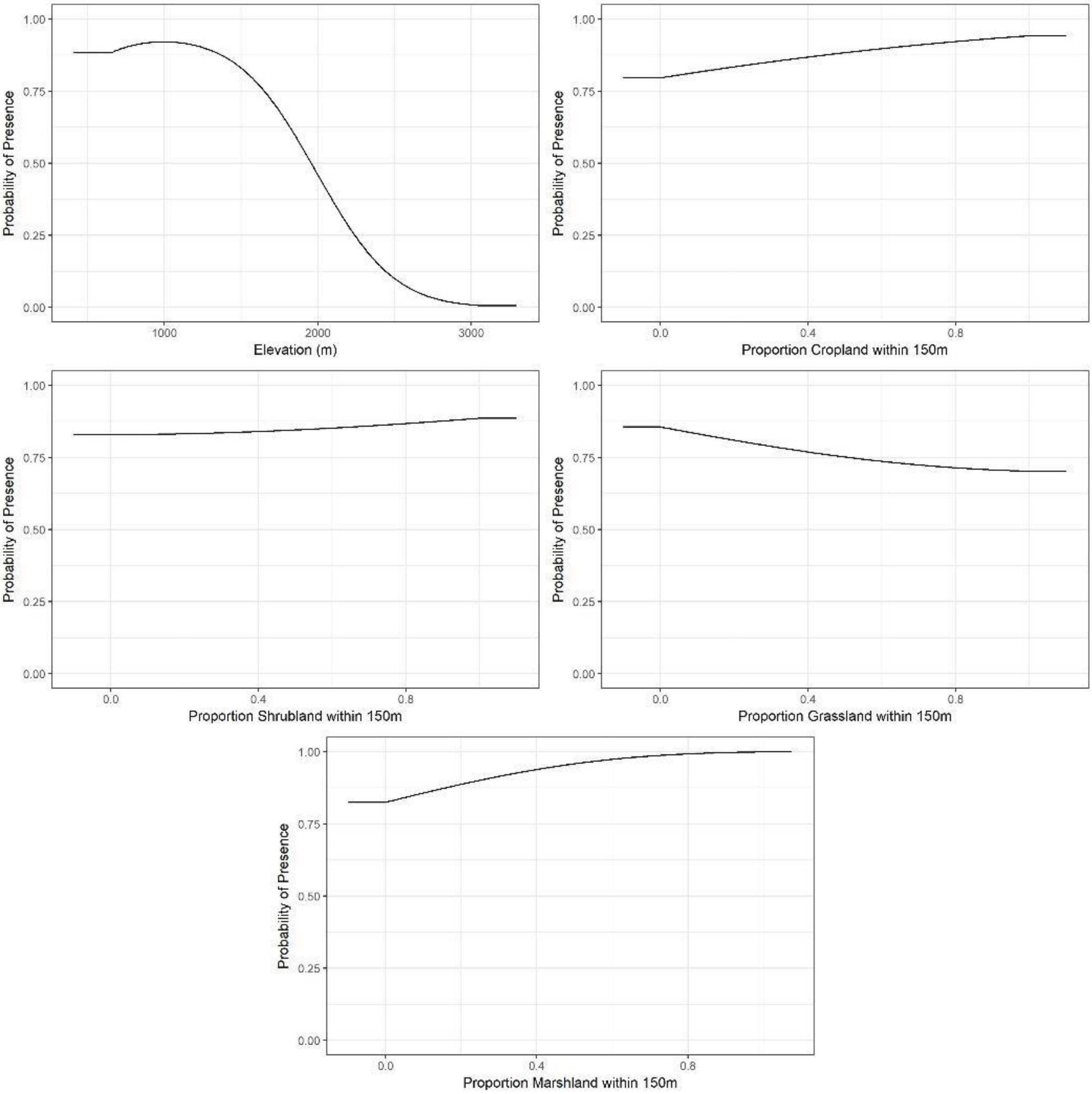

Figure 9. Response variable effect sizes for geographic and habitat features influencing Short-eared Owl presence, derived from MaxEnt model LQ0.5 using presence and pseudo-absence data from project WAFLS 2015, 2016, and 2017.

Using the full combination of climate, geographic, and habitat variables described in Figures 8 & 9, we were able to plot the likelihood of Short-eared Owl land-use across the study area (Fig. 10). Furthermore, replacing only the climate variables within the model with future climate variable projections for the year 2070, we were able to project the future likelihood of Short-eared Owl land-use across the study area (Fig. 10). This climate view is considered conservative as it assumes no change in land cover, only in climate. We expect the land cover to also change with a change in climate, which could make the change in likelihood of presence even more dramatic.

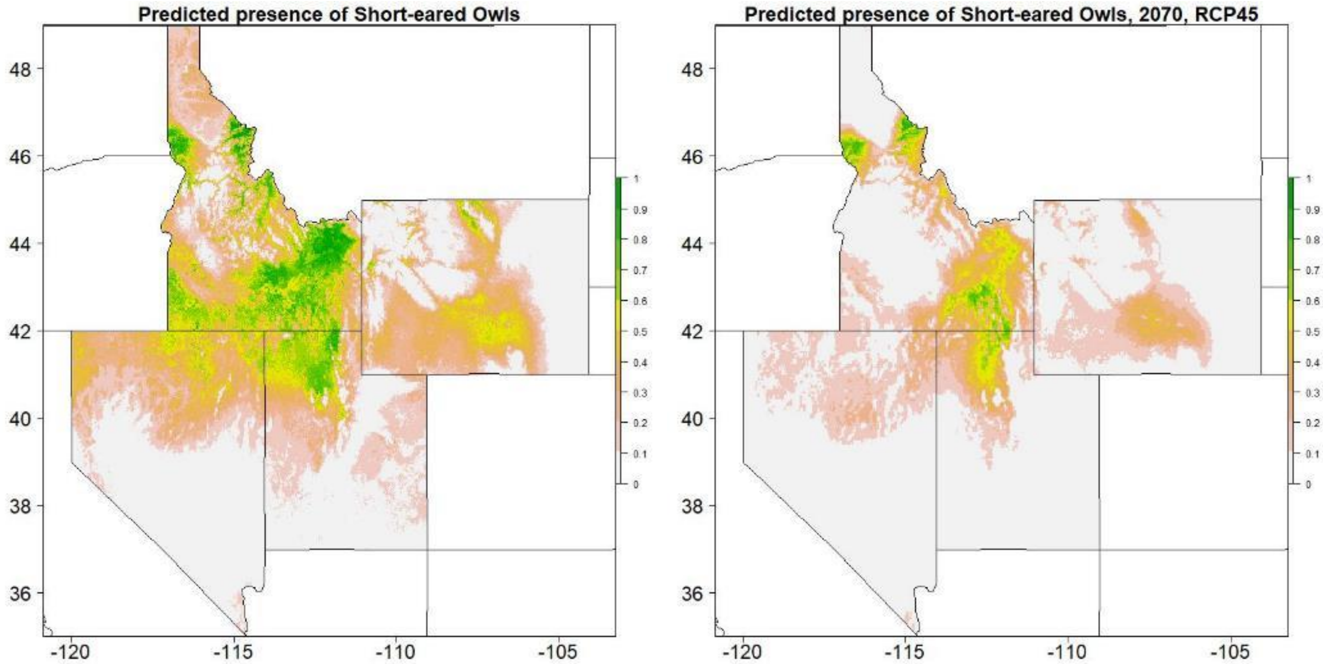

Figure 10. Study-wide predicted habitat suitability for Short-eared Owl presence, using current and future climate scenarios, derived from MaxEnt model LQ0.5 using presence and pseudo-absence data from project WAFLS 2015, 2016, and 2017. Future climate is projected to the year 2070 using the Representative Conservation Pathway 4.5 assumptions generated by Hadley Centre Global Environment Model version 2.

DISCUSSION

We successfully engaged a large group of participants, mostly citizen-scientist volunteers, to survey for Short-eared Owls across a broad geographic region in the Intermountain West. The continued expansion from two states to four further increased the strength of this study. We believe this to be the largest species-specific survey for Short-eared Owls in the world. The analysis identified important Short-eared Owl habitat associations, providing insight into which habitats in the region may be most important for conservation and further study. The results will be integrated in the various state-wide action plans to address the conservation concerns for this species.

For the first time in three years we did not have a sufficient number of detections to produce a quality abundance estimate for Idaho, nor did we have sufficient number in any of the other states. The survey occupancy estimates, generally more reliable than abundance estimates, were successfully estimated and found to have decreased to about 1/3 of their 2015 and 2016 values in Idaho, and down in Utah as compared to 2016 even though we contracted the survey stratum to a higher quality subset of the state. This decline in occupancy rate may signify a continued decline in the population, or more likely due to the dramatic nature of the decline, may simply represent the expected short-term variability in population size related to prey abundance for which this species is known (Clark 1975, Korpimäki and Noordahl 1991, Johnson et al. 2013). Wiggins et al. (2006) and Johnson et al. (2013) each suggest that consistent surveying over a time span exceeding multiple prey cycles is required before trend estimation should be performed.

In addition to the overall occupancy estimates used as a surrogate for abundance, the multi-scale occupancy analysis provided key insight into owl detectability from both weather and timing, and point scale impacts such as grazing. Consistent with Larson and Holt (2016), our results noted an increase in the probability of detection the closer to the end of civil twilight that the survey was performed. Not surprisingly, we also found that the probability of detection was higher in calmer wind conditions. We suspect this is both the result of the wind's effect on the surveyors and the wind's effect to discourage male Short-eared Owl's courtship flights. Two years ago, we started collecting data on grazing evidence surrounding the survey points. In 2016, no impact of grazing was measured (positive or negative), but this year we found a moderate impact, with occupancy higher in areas of moderate evidence of grazing, and lower in areas of no grazing or high degrees of grazing. This result is contrary to the results of Larson and Holt (2016) that had no detections in grazed habitats. We will continue to evaluate this result in future years. This also dovetails into our 2018 plans to launch a grazing specific program in partnership with the Grouse and Grazing project led out of the University of Idaho. This manipulative landscape study is expected to provide very high-resolution measurement of the sensitivity, or lack thereof, of Short-eared Owls to various grazing practices.

Cattle at Short-eared Owl survey point on transect Idaho-028.
Photo by project volunteer Sharon Darling Hayes, April 7, 2016.

The Maximum Entropy modeling was newly introduced this year. It was chosen as a more effective way to analyze habitat associations as it has fewer restrictions on the type of data integrated into the analysis (e.g., less sensitive to correlated predictor variables). MaxEnt modeling is generally more comprehensive in its variable selection, allowing a more complex set of variables that more closely resemble the complexity of the study area. This is evidenced by the 13 variables that we report on as compared to the more limited set passing the threshold in our occupancy models.

The climate data included in the MaxEnt analysis allowed us to explore the risk to this species of predicted climate change. The variables chosen and their impacts clearly illustrate this risk. The owls are associated with habitats where precipitation occurs throughout the year with only a moderate level of seasonality. Climate predictions for our region suggest that annual precipitation may remain constant or slightly increase, but when that precipitation occurs during the year is expected to shift. Seasonality is predicted to increase with summers continuing to become drier. This is the primary factor influencing the range contraction illustrated in the future study-wide predictions.

Storm over the mountains on Idaho-029. Photo by project volunteer Michelle Jeffries, April 14, 2017.

Storm over the mountains on Utah-003. Photo by project volunteer Keeli Marvel, April 8, 2017

The habitat components of the MaxEnt models fit our past year's results from Idaho and Utah, suggesting a positive association with shrubland, cropland, and marshland, and a negative association with grassland. In many parts of its range, the Short-eared Owl is considered a grassland species (Clark 1975, Holt et al. 1999, Swengel and Swengel 2014). However, much of the Intermountain West has been converted to invasive cheatgrass (*Bromus tectorum*) and other invasive annual plants (West 2000). Swengel and Swengel (2014) note that in the Midwest, Short-eared Owls most often nest in large areas of contiguous grassland, with heavy litter or "rough grassland". The structure of the grassland in their study is quite different from the more homogenous, low litter grass found in invasive grasslands in the Intermountain West. Short-eared Owls in other studies appear to occur less often in landscapes similar to the invasive grasslands of the West (Clark 1975, Fondell and Ball 2004). In the Intermountain West, shrubland habitats usually provide more structural complexity than grasslands, which may explain the association of the owls with this primary habitat type in our area. However, because much of the Intermountain West has been converted to invasive grasslands, and these are lumped together with native grasslands within our chosen Landfire classification system, the importance of intact, native grasslands may be masked by the overwhelming presence of invasive grasses within our study area.

Short-eared Owl flying over marshland. Photo by project volunteer Elizabeth Burtner, April 16, 2017.

The measured association with agricultural lands could be the result of a number of factors or combination thereof. Owls could by pushed to agricultural lands as a result of habitat degradation occurring in the non-agricultural landscape as a result of cheatgrass invasion, development, and fire (West 2000, Fondell and Ball 2004). Agricultural lands may also provide higher prey density (Moulton et al. 2006), attracting owls to occupy these areas over more native landscape. Some agricultural lands may also provide plant structure more similar to the owls native prairie landscape that they use in the Midwest. As our surveys were limited to roads and many of the roads were built to support agriculture, we may not have adequately sampled undisturbed natural habitat (Gelbard and Belnap 2003), which is becoming increasingly rare in the region.

Our study had several potential sources of bias, which was one reason we performed multiple analyses. The abundance analysis is more sensitive to sources of bias than the occupancy analysis, but most of these biases do apply to both analysis types. Potential sources of bias that could have increased our estimates (both occupancy and abundance measures) included placement of the survey route along the best habitat within the grid, misidentifying species (e.g., counting a distant Northern Harrier as a Short-eared Owl), and identifying owls further than 1km from the survey point. Potentially biasing our results lower included not detecting birds less than 1km due to obstructions or local landscape relief, not sampling the areas that fell outside of our stratum (e.g., grids with only 68% of target habitat instead of >70% target habitat), and the potential influence of road based surveys. Roads enable land use that can result in fragmented landscapes which have been shown to have a negative association for Short-eared Owls in the Midwest (Swengel and Swengel 2014). Additionally, Short-eared Owls could be negatively affected by road noise, which has been shown for other avian species (e.g., Ware et al. 2015).

This project was only viable with the generous support of our volunteer base. However, the volunteer base was likely the largest variance introduced to our project. The skill set of our volunteers ranged from expert to beginner. We emphasized training during the project, but volunteers were not evaluated on their skills; a process more often performed on professional surveys. However, checking datasheets for quality and completeness confirmed that most of our volunteers were very diligent in completing the assigned tasks, very often exceeding the detail provided by professional biologists. The biggest unknown we had pertained to the correct identification of Short-eared Owls. We provided training materials for proper identification and emphasized to volunteers to only record owls that they were certain were Short-eared Owls, as our methods were robust to false negatives. Within our study area, the Long-eared Owl and Northern Harrier would be the most likely species' to confuse with a Short-eared Owl. We focused on the distinction within our training materials. In an effort to mitigate species confusion, we asked volunteers to record the number of Long-eared Owls and Northern Harriers, and to record the number of birds that they believed to be Short-eared Owls, but could not fully confirm. Our volunteers reported 31 instances of possible Short-eared Owls that could not be fully confirmed, suggesting that we were effective in mitigating this risk. As with most programs, quantifying the magnitude of the bias from each factor is not feasible. We do believe that these biases have been managed as best as possible within the program and that the actual population and effect sizes fall well within our confidence intervals.

We were successful in meeting all of our objectives utilizing a largely volunteer labor force. We suggest that the use of a distributed volunteer labor force resulted in greater efficiency in survey coverage, resulted in more surveys completed, and ultimately resulted in a higher quality inference than would have occurred using only professional staff. In subsequent years we expect to continue and promote the use of citizen scientist volunteers, and maintain the basic structure of the 2015 – 2017 programs. We expect to expand the surveys to additional states in 2018, by completing at least 40 transects per state and maintaining a state-based stratum within the overall analysis to identify local habitat differences and generate state-by-state estimates of abundance. Lastly, we expect to refine the habitat model to collect more specific habitat data at each point.

CONCLUSION

We successfully recruited a large group of volunteers to sample a broad geography within the Intermountain West for Short-eared Owls during the 2017 breeding season. Our results have identified specific habitat associations, confirming that habitat use may vary regionally. While we were not able to establish abundance estimates this year, our occupancy rates provide a great surrogate for abundance and will act as a baseline for further studies to identify and quantify any trends that may be occurring in the population. We have confirmed that our study design was sufficient to meet our objectives and will only require minor modifications moving forward. We are actively working to expand this successful program to other states within the breeding range of the Short-eared Owl.

Happy first year volunteers, Amie and Lyle Wiley, Wyoming-028, April 13, 2017.

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Appendix I: 2017 Survey Participants

A. Kristof, A. Nies, Aaron Ambos, Acacia Sprague, Aimee Kite, Alek Mendoza, Alex Takasugi, Alisha Mosloff, Allan Wylie, Almeta Helmig, Amanda Holt, Amie Wiley, Anastasia Morse, Andrew Blomberg, Andy Thomson, Anika Mahoney, Annette Hansen, Austin Young, Avery Kane, Barbara Pete, Ben Briggs, Ben Wishnek, Beverly Boynton, Bill Robertson, Blair Briggs, Bob Sweatt, Bobby Jones, Bonnie Schonefeld, Brad Crane, Brandon Ransom, Brenda Pace, Bret Mossman, Brett Bunkall, Bri McCloskey, Brian Barber, Brian Maxfield, Britney Zell, Brittany Roberts, Bruce Holt, Bruce Lawson, Bruce Pope, Bryant Olsen, C. Braastad, Caileigh Felker, Caleb Hansen, Cathy Eells, Cavett, Chad Anderson, Chandler, Charlie, Charlotte Eberlein, Cheryl Huizinga, Chris Cleveland, Chris Fichtel, Chris O' Brien, Chris O'Brien, Christopher Pedroza, Chuck Trost, Cindy Hyslop, Claire, Clif Albrecht, Cody Bish, Colene Paradise, Concetta Brown, Connor Kotte, Cordell Peterson, Cory Braastad, Craig Okraska, Dain Christensen, Dale Reynolds, Dale Schrickling, Dan Thiele, Dana Nelson, Daniel James, Daniel Johnson, Dave Pace, David Davis, David Lehman, David Vanek, David Wheeler, Dawn Stryhas, Dean Tonenna, Debbie Heaton-Lamp, Deborah Drain. Vance Drain, Dena Santini, Denise Hughes, Dennis Saville, Dennis Serdehely, Destany Littlesky Pete, Don Weber, Donna Whitham, Dora Berryman, Doug Hunter, Eaton, Elizabeth Boehm, Ellis Hein, Emma Baker, Eric Ethington-Boden, Erika Peckham, Erin Nelson, Ernest Schrickling, Ethan Ellsworth, Evans, Frank Jenks, Franz Carver, Gerri Giglio, Grant Frost, Gretchen Baker, Gretchen Fitzgerald, Gretchen Vanek, Gretel Care, Gwyn McKee, Hilary A. Turner, Hill, Hillary Duncan, Hillary Williams, Holly Copeland, Holly Dalrymple, Izzy Guzman, Jace Taylor, Jacob Briggs, Jake Lang, James Loveless, Jamie Smith, Jana Weber, Jane Van Gunst, Janet P. Phillips, Jason Fibel, Jason Jensen, Jason Lynch, Jason Sutter, Jazmyn McDonald, Jean Robinson, Jeff Thompson, Jenni Jeffers, Jenny Locke, Jenny Sweat, Jeremy Jirak, Jeremy Telford, Jeremy Welch, Jesse Alston, Jesse Gomez, Jessica Snaman, Jessica Van Woeart, Jessie Holt, Jill Jensen, Jim DeWitt, Jim Dowling, Jim Francis, Jim Spencer, Jim VanArk, Jimmie Yorgensen, Joanna Kane, Joe Sandrini, John Harlin, John Young, Johnna Eilers, Jonathan Padgett, Joseph Dane, Joyce Pole, Judi Zuckert, Julie Woods, Karen Leibert, Kathie Valentine, Kathryn Grandison, Kathy Lopez, Kathy Paulin, Katie Taylor, Kaycee Bish, Kaycie Adams Deem, Kaylyn, Keeli Marvel, Kellie Carter, Kelly McKinnon, Ken Harris, Kendra David, Kenna Holt, Kenneth Pete Jr., Kenny Pete, Kosmos Sutter, Kristin Szabo, Kristin Telford, Kyle Smith, Larry Hyslop, Laura Jones, Laura Lockhart, Lauri Taylor, Laurie Averill-Murray, Leah Lewis, Leah Richardson, Leroy Christensen, Leslie Yorgensen, Lewis Hein, Libby Burtner, Linda Serret, Linda Tunnell, Lindsay Hooker, Lindsey Sanders, Lisa Jasumback, Liz Taylor, Lyle Hamilton, Lyle Wiley, Lynell Sutter, Mackenzie Jeffress, Maggie Hallerud, Marco Ovando, Margaret Dowling, Marie Adams, Marilyn Olson, Marjorie Chase, Mark Enders, Mark Jasumback, Mark Whitham, Marsha White, Mary Malmquist, Mary Pendergast, Matt Bent, Matt Howard, Matt lovejoy, Matthew Pendleton, Meg Fereday, Meg Horner, Meg Tracey, Melinda Cowan, Melissa Nissonger, Melody Asher, Michael Adams, Michael Frazier, Michael Myers, Michelle Jeffries, Mike Kane, Mike King, MIke King, Mike Malmquist, Mike Santini, Mike Toth, Moira Kolada, Monica Morales, Monro, Moretz, Morgann Jensen, Nancy DeWitt, Nancy Herms, Nancy Hoffman, Nancy Kiser, Nancy Light, Natasha Hadden, Nate Turner, Neil Paprocki, Nick Prasser, Noelle Jensen, Norma Johnson, Nycole Burton, Paige Hellbaum, Pat Weber, Patricia Hallingstad, Peckham, Rachael Cervantes, Rachel Williams, Randi Rollins, Randy Harrison, Randy Smith, Raymond White, Rebecca Bonebrake, Reid Olson, Renati Sutter, Rich Hayes, Richard Nelson, Richard Nelson. Jacob Nelson, Rick Eells, Rob Lowry, Roger Laughlin, Roger Weber, Ron Lynch, Rory Lamp, Ross McCracken, Roy Averill-Murray, Sally Oviatt, Sally Watt, Samantha Phillips, Sammy Holt, Samuel Pole, Sarah Harris, Scott Bye, Scott Copeland, Scott Gibson, Sean Finn, Shaila Hood, Sharon Hayes, Sheri Weber, Sherree Sheide, Sophia, Stephen Chase, Steve Eberthard, Steve Heinrich, Sue Braastad, Sue Lowry, Susan, Susan Laughlin, Suzanne Jones, Suzi Holt, Tana Hunter, Teri Slatauski, Terri Pope, Terry Fieseler, Terry Shanahan, Theresa Saint, Tia Woods, Tim E. Griffith, Timi Saville, Tina Toth, Todd Caltrider, Tom Jones, Tracy Kelly, Tracy Kipke, Trisha Scott, Troy Fieseler, Troy Thompson, Valerie Fieseler, Vern Tunnell, Veronica Kratman, Vicki Allen, Vini Exton, Vivian Schneggenburger, W.D. Robinson, Wallace Keck, William Robbie, William T. Phillips, Willow Steen, Zach Wallace

Appendix II: 2017 Participant Affiliations

American Kestrel Partnership, Boise State University, Boise State University student chapter of The Wildlife Society, BOP, Bridgerland Audubon Society, Brigham Young University, Buffalo Bill Center of the West - Draper Museum of Natural History, Bureau of Land Management, Bureau of Land Management - Carson City District, Bureau of Land Management - Ely District, Camas National Wildlife Refuge, Cheyenne High Plains Audubon Society, Duck Valley FFA, Duck Valley Greenhouses, Friends of Black Rock-High Rock, Golden Eagle Audubon Society, Great Basin National Park, Great Plains Wildlife Consulting Inc., Great Salt Lake Audubon Society, Hawkwatch International, Idaho Birders Online [IBLE], Idaho Birding, Idaho Department of Parks and Recreation, Idaho Master Naturalists, Idaho Master Naturalists - Henry's Fork Chapter, Idaho Master Naturalists - McCall Chapter, Idaho Master Naturalists - Sagebrush Steppe Chapter, Idaho Master Naturalists - Upper Snake Chapter, Intermountain Bird Observatory, Laramie Audubon Society, National Audubon Society, National Park Service - City of Rocks National Reserve, National Wildlife Refuge Association, Natural Resources Conservation Service, Nevada Department of Wildlife, Nevada Natural Heritage Program, Owyhee Combined School Science Club, Peregrine Fund, Pheasants Forever, Portneuf Valley Audubon Society, Prairie Falcon Audubon Society, Raptor Inventory Nest Survey (RINS), Red Cliffs Audubon Society, Red Desert Audubon Society, Salt Lake Center for Science Education, Sho Pai Tribes Wildlife and Parks, Snake River Audubon Society, Southern Nevada Water Authority, Southwestern Idaho Birders Association, Sublette County birders, Teton Raptor Center, The Nature Conservancy, The Wildlife Society, Tracy Aviary, U.S. Department of Defense - U.S. Army, U.S. Fish and Wildlife Service, U.S. Fish and Wildlife Service - Bear Lake National Wildlife Refuge, University of Wyoming, University of Wyoming at Casper, US Geological Survey, USDA Forest Service, Utah Birders, Utah County Birders, Utah Division of Wildlife Resources, Utah State University Eastern, Utah State University Student Chapter of The Wildlife Society, Wild Utah Project, Wyobirds, Wyoming Game and Fish Department, Wyoming Natural Diversity Database

Appendix III: 2017 Protocol

Other partners include: Idaho Bird Conservation Partnership, Idaho Fish and Game, Tracy Aviary, Utah Department of Natural Resources, Wyoming Game and Fish

Western Asio Flammeus Landscape Survey (WAFLS) Protocol

Equipment Needed:

1) GPS unit or Smartphone. We will use “decimal degrees” for all coordinates (e.g., IBO Offices are located at 43.605187°, -116.211022°). There are many free smartphone apps to provide you with GPS coordinates. Here are some suggestions:

> Android: “GPS Coordinates” app by Woozilli, Inc. It is free, easy to use and does not require cell service to operate. Decimal degrees shown by default.
>
> iPhone: Try “Current Altitude Free” from Hearn Apps, LLC.
> or: “Easy GPS” from 2kit consulting
> or: “Free GPS” from CodeBurners

2) datasheet and map
3) Civil twilight times for your grid
4) clipboard (or hard surface to write on) and writing utensil (pen preferred)
5) binoculars
6) Stopwatch or clock to keep track of minute-by-minute intervals of the survey.
7) survey partner (optional… but its easier and more fun with two people; record # of observers)
8) This survey protocol (for reference)
9) Flashlight for reading datasheet at last point

Dates of Surveys:

Surveys should be conducted during the period of short-eared owl (SEOW) pair formation. These dates vary by state and by elevation so check the information for the grid you signed up for. Surveys must be done between these dates. Each survey route assigned to you should be surveyed twice during this period – once during the first 3-week visit window, and once during the second 3-week visit window. We prefer to have at least one week between the two visits, but this is not required.

Timing of Surveys:

Surveys should be conducted during the time of day when Short-eared Owl courtship is occurring and can be seen by a human observer. Therefore, surveys must be performed over 90 total minutes, between 100 minutes and 10 minutes before the end of **civil twilight** (later than sunset, defined to be when the sun is 6 degrees below the horizon) for the township you are in. We have created an online table for each survey route and date. Please look up survey start time and end time prior to leaving for your survey. These times are specific for your route and for your day of survey.

Civil twilight schedules for all Grids: https://drive.google.com/open?id=0Bwslm-BudQ3NeG5YSF9zNlI5MDg

Weather:

Your survey should be completed during periods of good or fair weather. Clouds are fine, but you should avoid any steady rain or snow. Breezy conditions are also ok, but strong winds should be avoided. Previous survey results have found that detection rates of Short-eared Owls decrease with higher winds.

Choosing Route:

If you are choosing your own route within a grid, please remember that you will need a five mile stretch of road, with as few turns as possible. The grids are 6.2 miles square, so your survey will need to span most of the grid. Choose a road with little traffic, where you can safely pull off of the road to survey. Choose a road with as much diversity as you can find (e.g., combinations of shrubland, grassland, and agriculture; the free Google Earth software is very useful for this). Zoomed in single grid maps are available on the portal. If uncomfortable with laying out the points, just ask us for help. If your route includes a sharp turn, you will have to travel ¾ of a mile to the next point to ensure that the points are at least ½ mile apart. If you find that your route in inaccessible due to private land access, muddy roads, or other issues, just notify us. We expect to have a few failed routes. Unfortunately, we are not able to preview all routes statewide. Note: you will survey the same points on each of your two visits.

Mileage, Hours and Affiliation:

The datasheet asks for your total round trip mileage to complete the survey (estimates are fine). These are vehicle miles and are not duplicated per person. There are two fields, one for volunteers and one for mileage that is being paid by a state or federal agency (state and federal employees may still be volunteers if they are on their own time and in personal vehicle). We also want to know your total time investment (please include initial sign-up, studying, and preparation in your first visit, surveying, and data entry). Please add this up for all people participating (e.g., 2 people for 4 hours = 8 hours total). Hours is also split by whether the hours are volunteer hours or being paid by an agency. This will be used to report on the overall volunteer contribution. Affiliation refers to which birding, volunteer, or professional group(s) you heard about this opportunity through or participate in. This may include online groups. We want to recognize those organizations as well (e.g., Golden Eagle Audubon, Southwestern Idaho Birders, McCall Master Naturalists, Professional (BLM), Professional (IDFG), Idaho Birding, IBLE, …).

Survey Procedure:

Each survey consists of *at least* 8 observation points, spaced 800 meters (0.5 miles) apart, but may extend up to 11 survey points. Active surveying is performed at each point for 5 minutes. *Arrive at the first point at least 5 minutes in advance of the beginning of the survey to organize data sheets, record weather conditions, etc.* We also suggest visiting the points and collecting habitat data prior to the survey so to maximize the available time during the survey window.

1) Locate a start point of the survey (surveys can begin at either end of the established route) using a GPS unit or smartphone. There are many free smartphone applications that will provide you with coordinates. We will use "decimal degrees" for all coordinates (e.g., IBO Offices are located at 43.605187°, -116.211022°). Please record at least 5 digits to the right of the decimal point. This may require a settings change on your GPS or Smart Phone. Some units may report the longitude as 116.211022 **W** instead of **-**116.211022. That is fine, we will drop the "W" and add the "-" later.

2) Identify the best vantage point within approximately 50 meters of the survey point. This vantage point may be a slight mound off the roadway, or it may be the bed of your truck, or if terrain is relatively flat, it may be the roadway in front of or behind your vehicle. Wherever you end up, make sure you have a good view of the surrounding landscape. **Please do not survey from within your car and do not trespass on**

private land to gain an optimal vantage point unless you have explicit permission from that landowner!

3) At the beginning of each 5 minute survey period, begin scanning the surrounding area, including ground and sky, for any SEOW presence. Surveys should be done using a combination of scanning with binoculars and scanning with the naked eye (and, of course, listening). All SEOW observations should be recorded on the data sheet. Best efforts should be made to avoid double-counting SEOWs within each 5-minutes survey, however, please note any observations at the next point if the bird is still visible.

For each Short-eared Owl detected, note how the bird was initially detected (sight or sound), which of the five minutes within the survey it was detected (indicate all minutes observed; e.g., a bird may be observed in the second, fourth and fifth minutes, but not in first or third – three checks), the general direction of the bird from your location (to nearest N, NE, E, SE, S, SW, W, NW), the estimated distance to nearest 200m (roadside power pole are roughly 100m apart), the behaviors observed, the sounds heard, and the type of habitat over which the bird was located. Only mark birds that are ***positively*** identified. If you are unsure, there is a separate area on the datasheet top record that.

How SEOW detected (sight/sound)	Minutes Observed (Check all ☑)					Initial Direction	Initial Distance ☑				Behavior (list all - perched, foraging, direct flight, agonistic, courtship)	Vocalizations/Sounds (list all - hoots, barks, screams, wing clip, bill snap)	Habitat where observed (shrub, grass, ag, marsh, other)
	1	2	3	4	5	N, NE, E,…	< 200m	200 – 400m	400 – 600m	> 600m			

4) When 5 minutes of survey at a point are complete, quickly finish recording SEOW observations, recalling and recording any other positive raptor identifications you made, record the habitat (if not done prior, spend no more than 1 minute), and travel to your next survey point – 800 meters (0.5 miles) down the survey route. If you must turn a sharp corner, then travel 0.75 miles to the next point. These points should be determined by simply driving 0.5 miles in your car (or 0.75 miles if you turned a corner), stopping, and determining the best vantage point within 50 meters of your vehicle. At least 8 survey points should be completed within the 90 minute period allotted, but complete as many as you can up to 11.

Note: To complete at least 8 survey points in 90 minutes, you will have approximately 7 minutes between survey points. This is a suggestion but not necessarily a requirement. It does not matter if you only take 6 minutes between one, and then take 8 minutes between another set of points, as long as at least 8 points are completed in the 90 minute window. If road conditions do not permit the completion of all 8 points in the 90 minutes allotted, just complete a many as you can.

5) The survey is complete after 90 minutes have elapsed since the first survey began. Again, if for some reason you were unable to complete 8 points in 90 minutes, please make a note of this in the datasheet. The provided online time schedules indicate start time and the latest time to begin a point for each survey grid. After surveys are complete, **review the datasheet for completeness**.

Datasheet and Variables:
The provided datasheet has blanks for all the required survey information. Below are guidelines for each variable.

Air Temperature – measured in degrees Fahrenheit (F), to nearest 5 degrees is fine.

Wind Classification – measured using the Beaufort Wind Scale at the start point only. If wind conditions change dramatically during the survey, please make a note of this. See scale below:

- 0 = Calm: smoke rises vertically
- 1 = Light Air: Smoke drift indicates wind direction, still wind vanes

- 2 = Light Breeze: Wind felt on face, leaves rustle, vanes begin to move
- 3 = Gentle Breeze: Leaves and small twigs constantly moving, light flags extended
- 4 = Moderate Breeze: Dust, leaves, and loose paper lifted, small tree branches move
- 5 = Fresh Breeze: Small trees in leaf begin to sway
- 6 = Strong Breeze: Larger tree branches moving, whistling in wires (not recommended to survey)
- 7 = Near Gale: Whole trees moving, resistance felt walking against wind (not recommended to survey)
- 8-12 = Gale – Hurricane (DO NOT conduct survey in these conditions): Twigs breaking off trees, generally impedes progress.

Cloud Cover Classification – measured at start point only. Classified as **cloudy** (100% cloud cover), **mostly cloudy** (50-99% cloud cover), **partly cloudy** (1-49% cloud cover), and **clear** (0% cloud cover).

Owl Behavior Classification – recorded at initial detection of each individual owl (i.e. if same individual owl is re-sighted, do not change the behavioral classification) classified as **perched, foraging, direct flight, agonistic, or courtship** (Holt and Leasure 1993).

Owl Vocalizations/Sounds – any sound produced by a Short-eared Owl should be classified as **hoots, barks, screams, wing clapping, bill clapping** (Holt and Leasure 1993).

(new in 2017) **Initial Direction –** Record the general direction (e.g., N, NE, E, …) of where the bird was *first* detected.

(new in 2017) **Initial Distance –** estimated distance to where the bird was first detected. This is rounded to nearest 200 meters. Roadside power poles are typically 100 meters apart. The categories are roughly less than 2 power poles, 2 – 4 power poles, 4 – 6 power poles, or greater than 6 power poles away. This is an estimate, so do you best but don't worry if it is not accurate. You can practice your distance estimation prior to the survey in case your route does not have power poles.

Habitat where owl observed – The general classification of habitat where the owl was initially observed. For example, the point habitat might be 90% shrubland and 10% riparian, but the owl was observed in the riparian vegetation. If the bird is flying, what habitat was it flying over when initially observed.

Vegetation Cover Classification – measured at *each survey* point. This should be recorded for each survey visit. For most points the values may not change, but agriculture could change from stubble to dirt if the field has been tilled since the last visit. This is a quick assessment. Do not spend more than about 1 minute determining habitat. If you prefer to be less rushed, you may travel the route prior to your survey to establish points and record vegetation (recommended!).

Record values to the nearest **10%**. Recorded as percentage of various land types within approximately 400 meters/yards (1/4 mile) of each survey point (half distance between points). Values should total to 100%. **Shrubland** may include grass, but is determined by at least a regular distribution of shrubs. Shrubland is split into two categories – **low** = knee height or shorter, and **high** = greater than knee height. **Grassland** may include a few shrubs, but there should not be many and should not be regular on the landscape. Grassland has two possible categories – ***(new in 2017)*** **cheatgrass monoculture** (dominated by short cheatgrass), and ***(new in 2017)*** **complex grassland** (taller grasses, bunch grasses, diverse species [may also include cheatgrass]) **Agriculture** is broken down into four classes including **fallow** (land has not been used for at least a few years and is over-run by grass, weeds, and shrubs), **dirt** (ground has been tilled to bare dirt or very short stubble, not high enough to provide shelter for mice or voles), **stubble** (last year's growth is still present and is at least a few inches tall – enough to provide some shelter and refuge for mice and voles), and **green** (new growth for this year). Pasture is considered agriculture and should be put into nearest agriculture category. **Marsh/riparian** indicates the presence of water, riparian vegetation, reeds, or cattails.

Examples:

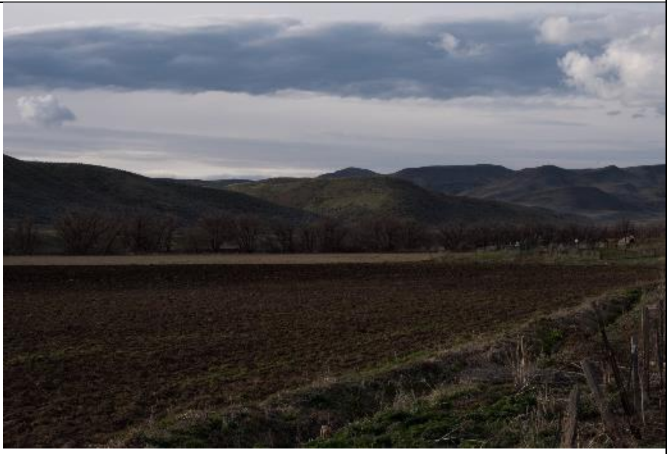
Tall Shrub (Photo: Jimmie Yorgensen)

Low Shrub (Photo: Von Welch)

Cheatgrass Monoculture
(Photo: nature80020, Creative Commons License)

Complex Grassland (Photo: BLM)

Agriculture – Green (foreground, Photo: Elizabeth Burtner)



Agriculture – Dirt (Photo: Elizabeth Burtner)

Agriculture – Fallow (Photo: Rob Miller)

Agriculture – Stubble (Photo: Rob Miller)

Marshland (Photo: Don and Sheri Weber)

Grazing and livestock – Does the habitat around the point look grazed (very short grass, trimmed shrubs, cow-pies etc.) and how much of the landscape appears grazed? If you are unsure, put zero. If animals are present, how much of the landscape do they have access to? Also, count the number of livestock within ¼ mile (it is ok to estimate of there are large numbers).

Other Observations – At the conclusion of each 5-minute point count, record the number of Long-eared Owls, Northern Harriers, ***(new for Idaho in 2017)*** Ferruginous Hawks, Burrowing Owls, or Long-billed Curlews seen or heard during the 5-minute point count. Please record the number observed, or zero if none were observed. A separate line is provided for any other raptors observed that were not specifically called out.

Data Submission:
We ask that you submit all data into the online data portal. This can be done after each visit of the survey (preferred) or after you complete both visits (two data submissions)

Online portal: https://form.jotform.com/70373511009144

Please submit your data no later than **May 30th**.

THANK YOU, THANK YOU, THANK YOU for contributing to this project!